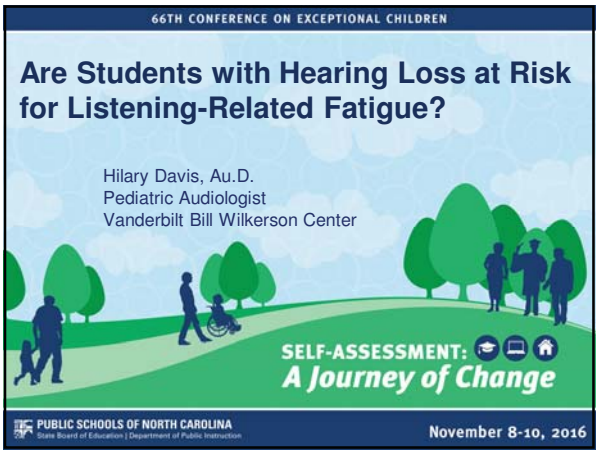

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Today's Goals

- Definitions of listening effort and fatigue
- Consequences of fatigue
- How do you measure fatigue?
  - Behavioral, physiologic, subjective

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What is Fatigue?

- Affects several areas of life including *physical*, *emotional*, and *cognitive or mental* domains
- **Physical fatigue**: reduced ability or desire to perform some physical task
- **Cognitive/mental fatigue:** feeling of tiredness, exhaustion, or lack of energy due to cognitive or emotional demands

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Aren't we all fatigued?

Fatigue is one of the most common complaints reported in primary care settings

- Transient fatigue is common, even in healthy populations

Recurrent, severe fatigue

- Uncommon in healthy populations, but common in many chronic health conditions
  - Previous reports in individuals with cancer, HIV AIDs, Parkinson's, Multiple Sclerosis

Slide from Gustafson, 2015

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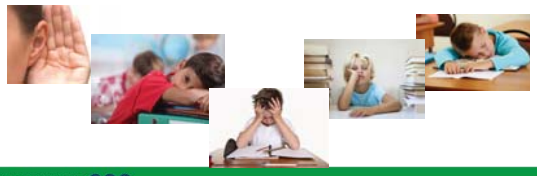
"When you are hard of hearing you struggle to hear; when you struggle to hear you get tired; when you get tired you get frustrated; when you get frustrated you get bored; when you get bored you quit." (Pichora-Fuller, 2003)



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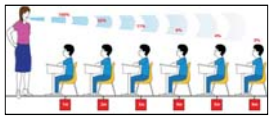
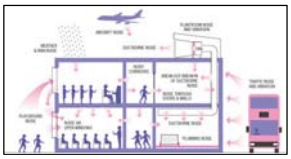
Listening in the Classroom





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Listening in the Classroom

- Degraded signal from effect of hearing loss and poor classroom acoustics
- Does the child put forth additional EFFORT to listen and understand in their typical listening setting? (i.e. classroom, cafeteria, gymnasium, after-school activities, etc)

CHL and AHL must increase mental effort compared to those without HL when attempting to detect, process, and respond to auditory stimuli (Hicks and Tharpe, 2002; McCoy et al., 2005)

- Increase in LISTENING EFFORT (Hornsby, 2013)

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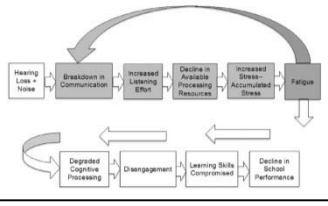
Does effortful listening affect fatigue?

Figure 1. Conceptual Model Linking Hearing Loss to Fatigue and School Performance. Shaded areas represent events that occur repeatedly throughout the school day.



Bess & Hornsby, 2013

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What does a CHL feel at the end of a school day? Is their ability to perform at school affected?

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Why do we care?
Negative Consequences of Fatigue

ADULTS	CHILDREN
Report stress, inattention, concentration difficulties	Higher rates of absenteeism at school
Reduced mental processing and decision-making capabilities	Poorer school achievement
Less productive and more prone to accidents at work	Difficulties with attention, concentration, and distractibility
Less active and more isolated	More likely to fail a grade

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Measuring Listening-Related Fatigue

Subjective Measures

- Questionnaires, rating scales that query an individual's mood or feelings
  - Discussed in Part 2

Objective Measures

- Does not require the individual to make a judgment about their fatigue
  - Behavioral: measuring decrement in performance
  - Physiological: measuring physiologic changes associated with mental effort
    - Cortisol
    - EEG

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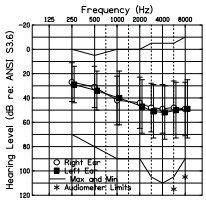
Vanderbilt Study on Listening Effort & Fatigue

- 6-12 year old children
  - Bilateral, mild to moderately-severe, permanent hearing loss
- Inclusion/Exclusion:
  - No cochlear implant users
  - General education classroom
  - Monolingual English speakers
  - No diagnosis of cognitive impairment, autism, or other developmental disorder
- Experimental group (n=59)
  - 30 males, 29 females
  - Age = 9.93 (1.92) years
- Control Group (n=42)
  - 25 males, 17 females
  - Age = 9.16 (2.32) years



Gustafson, 2015

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Visit Descriptions

- Initial Visit
  - Qualifying testing including non-verbal IQ and language measures
- Experiment 1: Cortisol
- Experiment 2/3: Simulating Fatigue (ERP and dual-listening tasks)*
- Experiment 4: Language Testing

*completed in both aided and unaided conditions in CHL

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Slide from Gustafson, 2015

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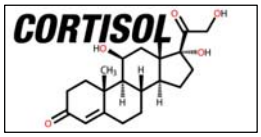
Research Question #1

- **Do children with mild to moderate sensorineural hearing loss exhibit increased fatigue (as measured by cortisol responses) throughout the course of a typical school day compared to their normal hearing counterparts? If so, how does the cortisol response differ?**



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Cortisol Patterns in Children with Hearing Loss

Hicks and Tharpe (2002)

- Children with mild to moderate hearing loss (n=10) and a control group (n=10)
- 5-11 years old
- Salivary cortisol at 9am and 2pm

No significant difference in cortisol levels between children with hearing loss and controls

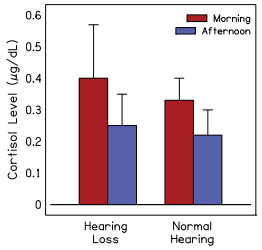

Figure adapted from original publication by Gustafson, 2015

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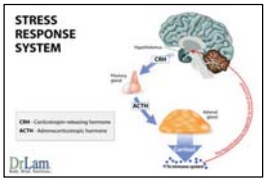
Stress, Cortisol, and Fatigue

- Stress is the body's reaction to change that requires a physical, mental, or emotional response
  - Stress is caused by good and bad experiences
- **Cortisol** levels provide a physiologic measure of stress
  - Regulated by the hypothalamic-pituitary-adrenal (HPA) axis
  - Related to sugar levels in the blood that fluctuate based on the need to mobilize energy



Gustafson, 2015

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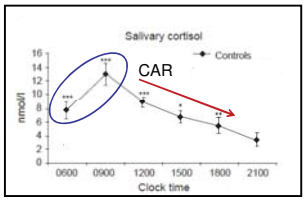
"Typical" Cortisol Patterns

In non-fatigued individuals, cortisol levels have a typical diurnal pattern

- Build-up of cortisol during sleep
- Rapid rise upon awakening
  - Cortisol Awakening Response; CAR
- Slow decline in cortisol throughout the day

Jerjes, et al., (2005).



Gustafson, 2015

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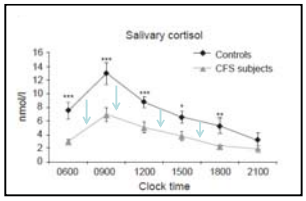
"Atypical" Cortisol Patterns

- Sustained stress or fatigue can lead to abnormal diurnal cortisol patterns
  - Reduced response with "Chronic Fatigue Syndrome"



Jerjes, et al., (2005).

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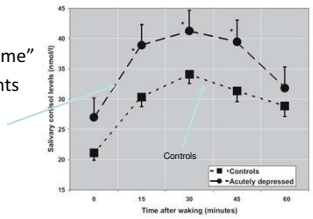
"Atypical" Cortisol Patterns

- Sustained stress or fatigue can lead to abnormal diurnal cortisol patterns
  - Reduced response with "Chronic Fatigue Syndrome"
  - "Elevated" CAR in patients with depression



Bhagwagar, Z., Hafizi, S., & Cowen, P. J. (2005).

Gustafson, 2015

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Vanderbilt Study: Cortisol Measurement

- Participants
  - Children with hearing Loss (n=32)
  - Control group (n=28)

- Six samples per day

1. Awakening*
2. 30 min post-wake up*
3. 60 min post-wake up*
4. 10:00 am
5. 2:00 pm
6. 8:00 pm*

- Sampled on two separate school days

*Samples taken by parents at home

Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby (2016)

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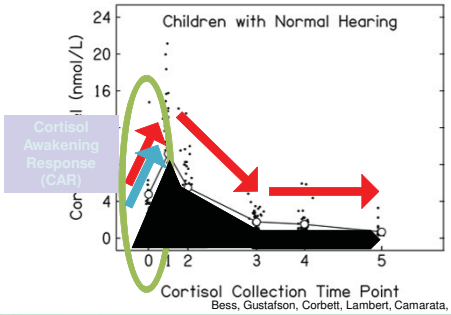
Measured Cortisol Levels



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby (2016)

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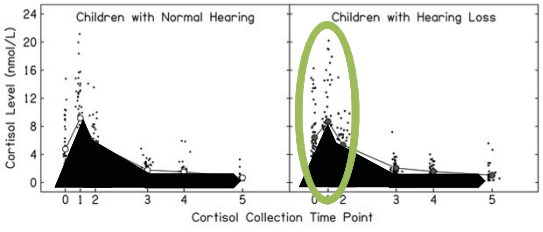
Comparing Measured Cortisol Levels

Modeling analysis revealed significant differences between group slopes – differences localized to the morning.



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby, (in press)

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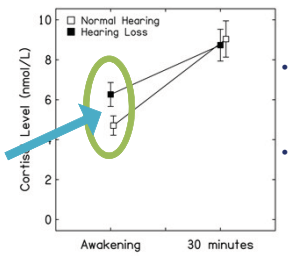
Comparing Measured Cortisol Levels



- Children with hearing loss have higher cortisol levels at awakening than controls
- Children with hearing loss have a reduced CAR compared to controls
- Suggests children with hearing loss are experiencing perceived stress and an increased burden of worrying about the upcoming day

Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby (2016)

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Chronicity of Stress

Hyperactive HPA axis

Hypoactive HPA axis

- Increased productions of cortisol
- HPA axis responds by reducing cortisol output over time
- Flattened cortisol profiles

De Vente et al., 2003; Fries, et al., 2005; Kudielka et al., 2009; Miller et al., 2007

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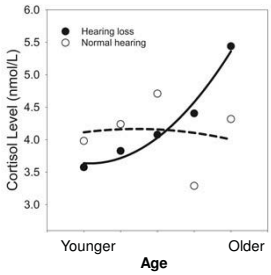
Child Age and Cortisol

Overall cortisol levels increase with increasing age for children with hearing loss, but not for the control group

Sustained stress due to hearing loss **might** be affecting their HPA system, potentially increasing the risk for fatigue over time



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby (2016)

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Vanderbilt Study on Listening Effort & Fatigue

Cortisol Findings:

Diurnal cortisol patterns in children with hearing loss are not "typical"

- Elevated levels at awakening and reduced CAR may suggest increased stress
  - Similar to adults with high "burnout"
  - Indicative of a dysregulation in HPA-axis activity

Gustafson, 2015

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Research Question #2

Will hearing-related fatigue for CHL differ from the normal hearing children as measured by ERPs?

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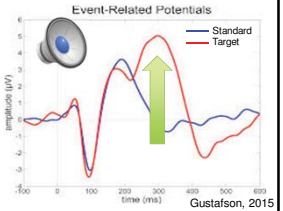
Measuring Fatigue with ERP

Event-related potentials (ERP) are changes in ongoing EEG activity that are time-locked to the onset of the auditory event

- Reflects change in brain activity associated with the processing of that stimulus

Centro-parietal P300 response

- Sensitive to fatigue due to cognitive processing (Murata, Uetake, & Takasawa, 2005; Uetake & Murata, 2000)



Gustafson, 2015

More fatigue → reduced amplitude

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Assessing Fatigue in the Lab

3 hours

ERP 1 → Speech Processing Tasks → ERP 2

- Participants
  - Children with hearing Loss (n=33)
  - Control group (n=29)
- Stimuli
  - Oddball paradigm (70/30)
  - Speech syllables ("gi" and "gu") at 65 dB SPL
  - Multi-talker babble at +10 dB SNR
- Procedure
  - 128-channel Geodesic sensor net
  - Passive task

Gustafson, 2015

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Assessing Fatigue in the Lab

3 hours

ERP 1 → Speech Processing Tasks → ERP 2

Series of activities focused on the recognition of speech in noise during tasks that required shared and sustained attention.

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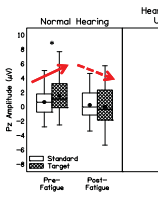
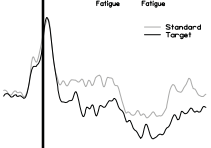
Ph



Children with normal hearing show reduced cognitive processing following sustained speech-processing tasks.

Changes are consistent with increased reports of fatigue on subjective assessments completed before and after speech-processing tasks (p<.05).

iguing Tasks



Key, Gustafson, Rentmeester, Hornsby, and Bess, (in prep)

NAL CHILDREN

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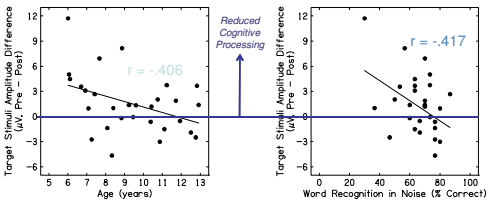
Who's at risk for fatigue?

Children with Normal Hearing



For children with normal hearing, **younger children** and those who have **poorer speech recognition** in noise were more likely to show reductions in cognitive processing due to

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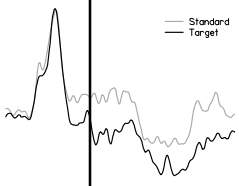

Normal Hearing (n=27)

Unaided Hearing Loss (n=33)

Children with hearing loss show delays in cognitive processing when compared to children with normal hearing.

Key, Gustafson, Rentmeester, Hornsby, and Bess, (in prep)

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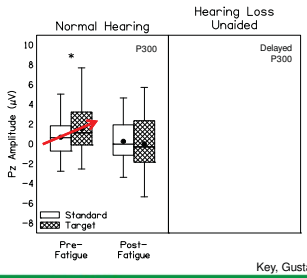
Physiologic Markers of Speech in Noise Processing



…with hearing …trends towards …eech in noise …n with normal …g.

Children with hearing loss also show reductions in P3 response after speech-processing tasks.

Key, Gustafson, Rentmeester, Hornsby, and Bess, (in prep)

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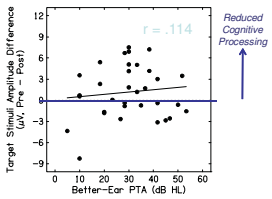
Who's at risk?

Children with Hearing Loss



This lack of relationship with degree of hearing loss is consistent with subjective fatigue data and suggests that children with even mild hearing loss are at increased risk for fatigue.

Age, Language, Nonverbal Intelligence, and Speech in Noise Recognition did not significantly accounted for variability in cognitive processing changes associated with listening-related fatigue.

Gustafson, 2015

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Vanderbilt Study on Listening Effort & Fatigue

Findings:

- Laboratory testing can induce listening-related fatigue.
  - Auditory-evoked P300 can be used to measure changes in cognitive processing associated with listening-related fatigue.
- Compared to children with normal hearing, children with mild-to- moderately-severe hearing loss:
  - demonstrate delayed cognitive processing time during active discrimination of speech in babble noise.
  - show similar consequences (i.e., reduced cognitive processing) of speech-processing related fatigue.

Gustafson, 2015

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Answers to Research Questions

1. **Do children with mild to moderate sensorineural hearing loss exhibit increased fatigue (as measured by cortisol responses) throughout the course of a typical school day compared to their normal hearing counterparts? If so, how does the cortisol response differ?**
   Yes, CHL have "atypical" cortisol patterns, suggesting increased stress.

2. **Will hearing-related fatigue for CHL differ from the normal hearing children as measured by ERPs?**
   Yes, CHL present show delays in cognitive processing of speech in noise discrimination. Both children with and without HL show reductions in cognitive processing secondary to speech-processing related fatigue.

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CHL at Risk for Fatigue?

YES!

So what do we do about it?

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Stick around for PART 2!

- Discussing subjective listening-related fatigue, commonly reported symptoms at home and in the classroom, and potential management strategies for CHL.

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Questions? Thoughts?

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http://my.vanderbilt.edu/listeninglearninglab

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